THE NORMAL TEMPERATURE DISTRIBUTION OF THE SURFACE WATER OF THE WESTERN NORTH ATLANTIC OCEAN

By GILES SLOCUM

[Weather Bureau, Washington, D. C., February 1938]

During 1937 the Marine Division of the United States Weather Bureau prepared, for the use of the Weather Bureau forecasters at Washington, and as an aid in air-mass analysis, a set of 12 monthly charts of normal water-surface temperature for an extensive region east of the North American continent, including, the Gulf of Mexico, the western half of the Caribbean Sea, and a limited portion of the western North Atlantic Ocean. The boundaries of this region are shown on chart 1.

Since that time, several requests have been received for copies of these charts. In order that such requests may be conveniently filled, and to make the charts available to the public and to such of the Weather Bureau field stations as may find them of value, these charts are now being published.

The data from which the charts have been compiled are water-surface temperatures measured by observers aboard ships cooperating with the Marine Division in the gathering of marine meteorological data. Some of these ships have sent in observations to the Weather Bureau over periods of many years. For instance, the Marine Division records show that the American S. S. *Tivives* has regularly sent in observations since 1919, and at the present writing has completed nearly 19 years of continuous cooperation. The *Tivives* has the longest continuous record under a single name which could be ascertained from an examination of the Marine Division's list of ships at present furnishing observations. There are many other ships with long records, including many ships which formerly furnished observations but which by now have been lost at sea, taken out of service, or for other reasons have ceased sending in observations.

There have been difficulties, largely mechanical, which have made it impracticable to assemble all available records into one summary of normal conditions, hence the period used in the compilation of the present charts includes only the 20 years, 1912 to 1931.

Each day the ship's observer takes one or more observations of a number of weather elements during the time that the ship is under way. The water-surface temperatures are recorded as a part of this routine observation, and those used in the present compilations were taken by either of two methods, namely the "bucket" method, or the "intake" method. The data gathered by ships using these two modes of observation, have been here assumed to be homogeneous and have been combined into one mass of data.

The greater number of the observations, about three-fourths, were made by the bucket method, and the other quarter of the observations by the intake method. The bucket observations are made by drawing up a sample of the surface water from the sea to the deck of the ship in a canvas or metal bucket, and immersing a thermometer, designed for this specific purpose, into the surface water sample. The observer is instructed to stir the thermometer in the water sample until the mercury column comes to a stationary height. The correct temperature of the water sample may then be read from the thermometer. In the intake method of observation, the water temperature is read from a permanently installed thermometer whose bulb is immersed in the condenser intake, where the water flows past the bulb of the thermometer as it enters the ship.

The bucket and intake observations are usually taken at Greenwich mean noon, but a number of ships also record either one additional observation at Greenwich mean midnight, or, three additional observations at 6 p. m., midnight and 6 a. m., Greenwich time. A few observations are made at local noon and at other miscellaneous hours. Except where otherwise noted, all references made in this paper to water-temperature observations are to Greenwich mean noon surface-temperature data.

There are uncertainties and inaccuracies involved in bucket and intake temperatures as observed on commercial ships, and the results obtainable are not suitable for precision studies of oceanographic problems. For such purposes, there are other and more accurate methods, such as the usually satisfactory thermograph sheet record, or the meticulously precise observations made with minutely calibrated instruments by trained scientific workers aboard well-equipped floating oceanographic laboratories. These two classes of precise measurements of surface water temperature are represented by fairly voluminous, but yet comparatively few available, data, gathered along only a few routes. This is a disadvantage when the data are to be used for meteorological and climatological purposes, where wide distribution and abundance of data are more important than extreme accuracy, however valuable such accuracy would be. The bucket and intake observations provide the only material available that fulfill the conditions of wide distribution and abundance.

The total number of observations of these two kinds in existence for all of the oceans is enormous, running well into eight figures, and is hundreds of times as great as the number of available precision measurements of surface-water temperature. The Weather Bureau has approximately 4,000,000 bucket and intake observations. This number has been so great that, until recently, it has been impossible to utilize any large fraction of the collection because of lack of facilities to treat such great numbers of observations. In 1934, however, the Civil Works Administration compiled data from more than 2,000,000 marine meteorological observations. The data were, in this compilation, transferred to Hollerith 45-column punch cards, and tabulated by Hollerith sorting and summarizing machines. Later, the Works Progress Administration undertook further summarizations of marine data on a more extensive scale. These summarizations are being deposited in the Marine Division. The compilations used in the present set of charts were made from the Civil Works Administration data, and it is hoped that normals for other regions may be computed from the Works Progress Administration compilations.

Other meteorological services have prepared similar charts in the past, which covered, in some cases, all or part of the region here treated. The British Meteorological Office has published [1] normal temperatures for 2° squares in chart form for the North Atlantic Ocean, the South Atlantic Ocean, the Indian Ocean, and the Mediterranean Sea. In the British charts, the normals for each square are entered to whole degrees, Fahrenheit, on maps of the oceans covered. The Netherlands Meteorological Institute using the same area unit, has charted

[1] Cf. Marine Observer, Vols., III, IV, V, and VII; Nos 25 to 60, and 73 to 84, inclusive.

the normals to tenths of a degree on the Centigrade scale, for the Atlantic Ocean [2] east of the 80th meridian, from 50° N. to 50° S., and for the Indian Ocean.[3] They have published 1° square normals [4] for the waters off the east coast of Asia from the Equator to 42° N., as far east as 145° east longitude, using the same temperature scale. Five-degree square normals [5] for the North Pacific Ocean and 1° square normals for selected areas along the east coast of Asia, are published in tables by the Japanese Government, using Fahrenheit entries.

Each of these compilations by foreign meteorological offices is based upon great numbers of observations. For instance, the British and the Dutch data were based on more than a million, which number at first thought, might seem adequate for the purpose of computing good normals for the entire ocean surface of the world. When however, a million or two of observations are considered as distributed over two or three oceans, over 12 different months, and over thousands of unit areas in each ocean, the average number of observations per unit area per month is not large. Furthermore, the observations are not distributed with any approach to uniformity. Instead, they are strongly concentrated in the areas traversed by the major ship routes, which are few in number. These routes of most frequent travel are somewhat different for different countries, since each government's data are most concentrated about the routes taken by vessels carrying the main imports and exports of the country. The result is that many portions of the earth's ocean surface are well represented by available observational material, but vast areas in out-of-the-way waters are utterly without representation.

To produce fully adequate normal temperature values for ocean-surface water requires a density of data such as is available from the more frequently-traveled ship routes. This ideal density cannot be obtained for any extensive portion of the globe, but for this one region, the data now made available approach closer to adequacy, quantitatively speaking, than in any previous compilation. This region is, in addition, that of most interest to the weather forecasters for the Eastern States, and therefore, a region for which a closer approach to adequate data is needed.

Although this is the region for which observations available to the United States Weather Bureau are most numerous per unit area, the distribution is very diverse even here, and varies, as shown on chart 1, from one observation per 1-degree square in the entire 20-year period, 1912 to 1931, to an average of about one a day per 1° square, a ratio of about 7,000 to 1. The squares with small circles on chart 1 are those within the region being considered where observations are least plentiful, but where even then, in the majority of 1° square thus designated, they are of about the average density found on the most adequately represented 10 percent of the earth's ocean surface. In these squares on chart 1, there are one, two, or occasionally five or six observations per 1° square for some one or more of the months of the year during the 20 years of record, but no observations whatever in the entire 20 years for some other month or months of the 12 in the year. While no reliable normal temperature can actually be computed for such areas, such data as are available are of some assistance in determining what temperatures are possible in these areas, and we may assume in the majority of cases that area units close to large masses of land have water-surface temperatures somewhere between those of the adjacent waters and those of the nearby harbor waters or of the littoral air temperatures. This does not constitute a really satisfactory approximation, but it is not an entirely worthless estimate, since, luckily, the areas within the limits shown on chart 1 which are so inadequately represented by observational data are small in size, embracing at most only a few 1° by 1° unit areas.

The squares with one diagonal on chart 1 are those for which some data are available for each month of the year for every 1° square. It is to be understood, however, that this is *not* the same as one or more observations for each of the *240* months in the 20 years, but only one or more for each of the *12* months of the year.

The upper limit in the number of observations in these squares is an average of 30 observations for each of the 12 months, or an average of 1½ observations a month during the 20 years. While the quantity of data assembled for these squares is still not sufficient to allow of making dependable normal temperature values for each 1° square, the support of data in the surrounding squares makes estimation of the approximate position of the isotherms possible.

The squares with two diagonals, more than half of the region included in the compilation, are those where 1° square normals are based on 31 or more observations, but on less than 190.[6] This is a more adequate number of observations for determinations of normal temperature, and averages computed from this many observations are probably almost as near to the true normal temperature as the use of a period of only 20 years can produce. This is because 20 years is so short a period to use in computing a normal surface-water temperature, that the variations in actual temperature about the normal for particular months and the semisecular trends in water-surface temperatures, limit the accuracy of the normals computed from the 20-year averages, however, accurately those 20-year averages be known.

The squares with black circles in addition to two diagonals are those where 191 or more observations are available for each monthly normal. With so plentiful a density of data as in these areas, it is possible, by combining several of the 1° squares into one group, to compile temperature history tabulations of small areas so as to make detailed studies of local condition .

In general, in spite of the great inequalities in the numbers of observations per unit area, there is a fair number of observations available for each of the majority of squares, and even where the density is inadequate, there are more data included in the present 1° square normals than have hitherto been used in computing the normals for areas four times as large, namely those compiled on the 2° square basis by other meteorological services. The Marine Division observations are so distributed that some of the spots which have been blanks, or have been represented by very scattered and scanty data on previous chartings, are, in the present set of charts, represented by considerable data. This is especially true for the portion of the Caribbean Sea included in this study. Previous compilations have been based upon records largely gath-

[2] Cf. Koninklijk Nederlandsch Meteorologisch Instituut, No. 110; Oceanographische en Meteorologishce Waarnemingen in den Atlantischen Oceaan. 4 vols.

[3] Ibid; Oceanographische en Meteorologische Waarnemingen in den Indischen Oceaan. 4 vols.

[4] Ibid; No. 115; Oceanographische en Meteorologische Waarnemingen in de Chineesche Zeeen en in het Westelijk Deel van den Noord Stillen Oceaan. 2 vols.

[5] The Mean Atmospheric Pressure, Cloudiness, Air Temperature, and Sea-surface Temperature of the North Pacific Ocean and the Neighboring Seas (English translation of title) Text in Japanese and English. Latest edition includes period from 1911 to 1935, inclusive.

[6] This arbitrary upper limit was chosen because when the density of observations per 1° square was originally charted, the results were tabulated to the nearest integral number of observations per 1° square per individual month. In particular, 31 to 190 observations for a normal temperature compilation value are the same as 2 to 9 observations on the average per individual month.

Chart 1. Density of Observations in Water Area for Which U. S. Weather Bureau Data are Used

(Plotted by Giles Slocum)

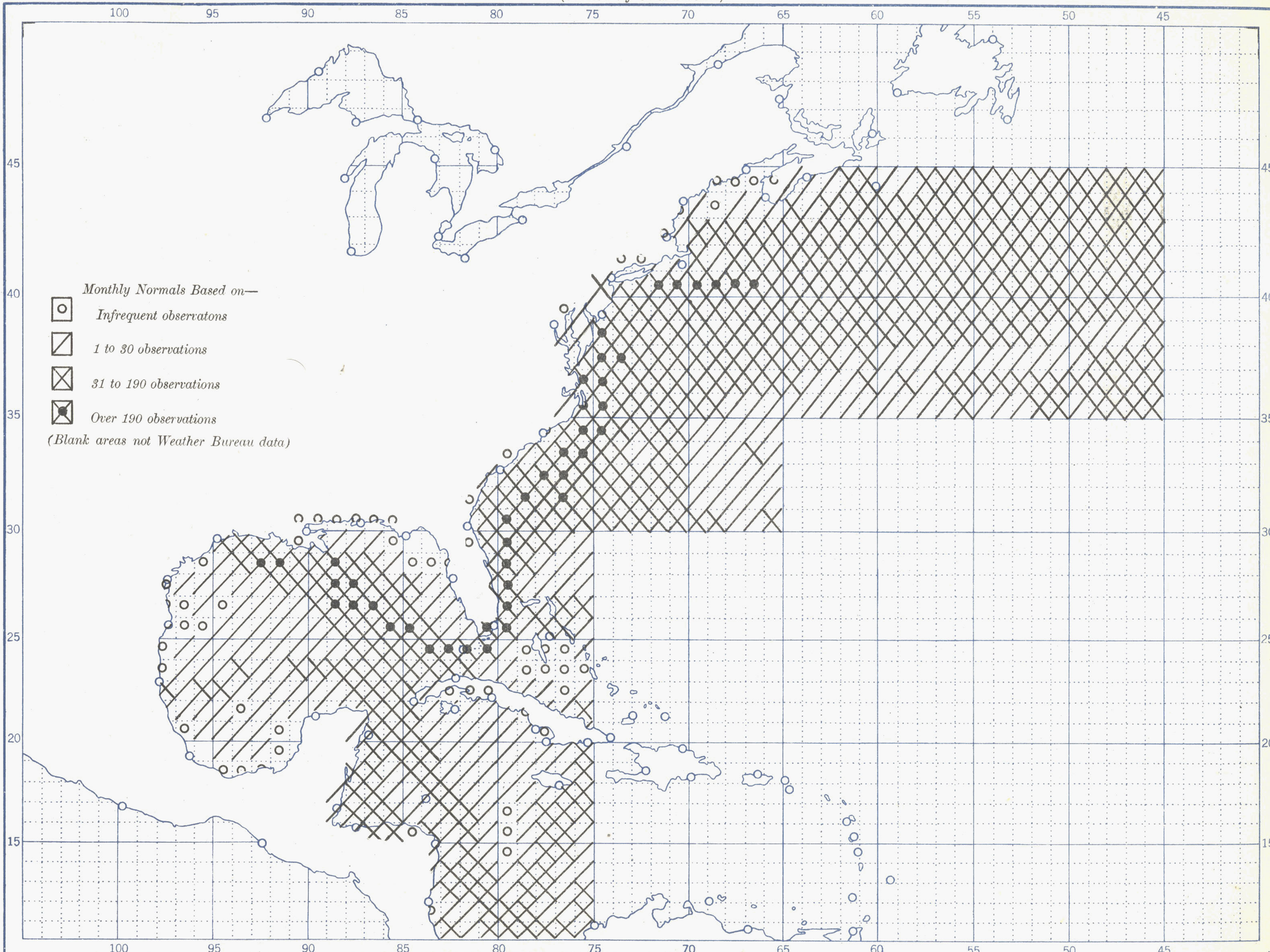
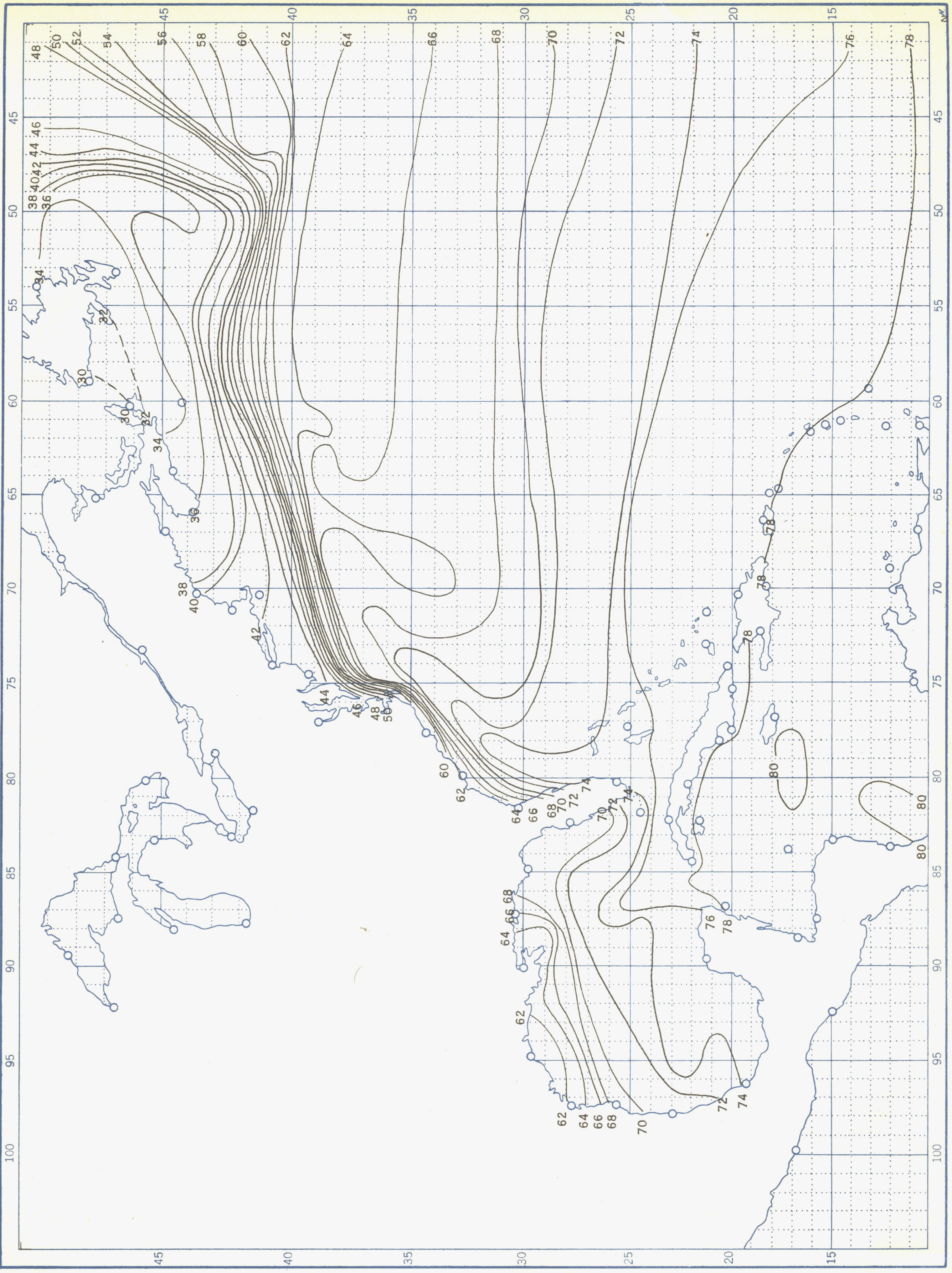


Chart 2. Average Sea-Surface Temperature (°F.) for January 1912-1931

(Plotted by Giles Slocum)



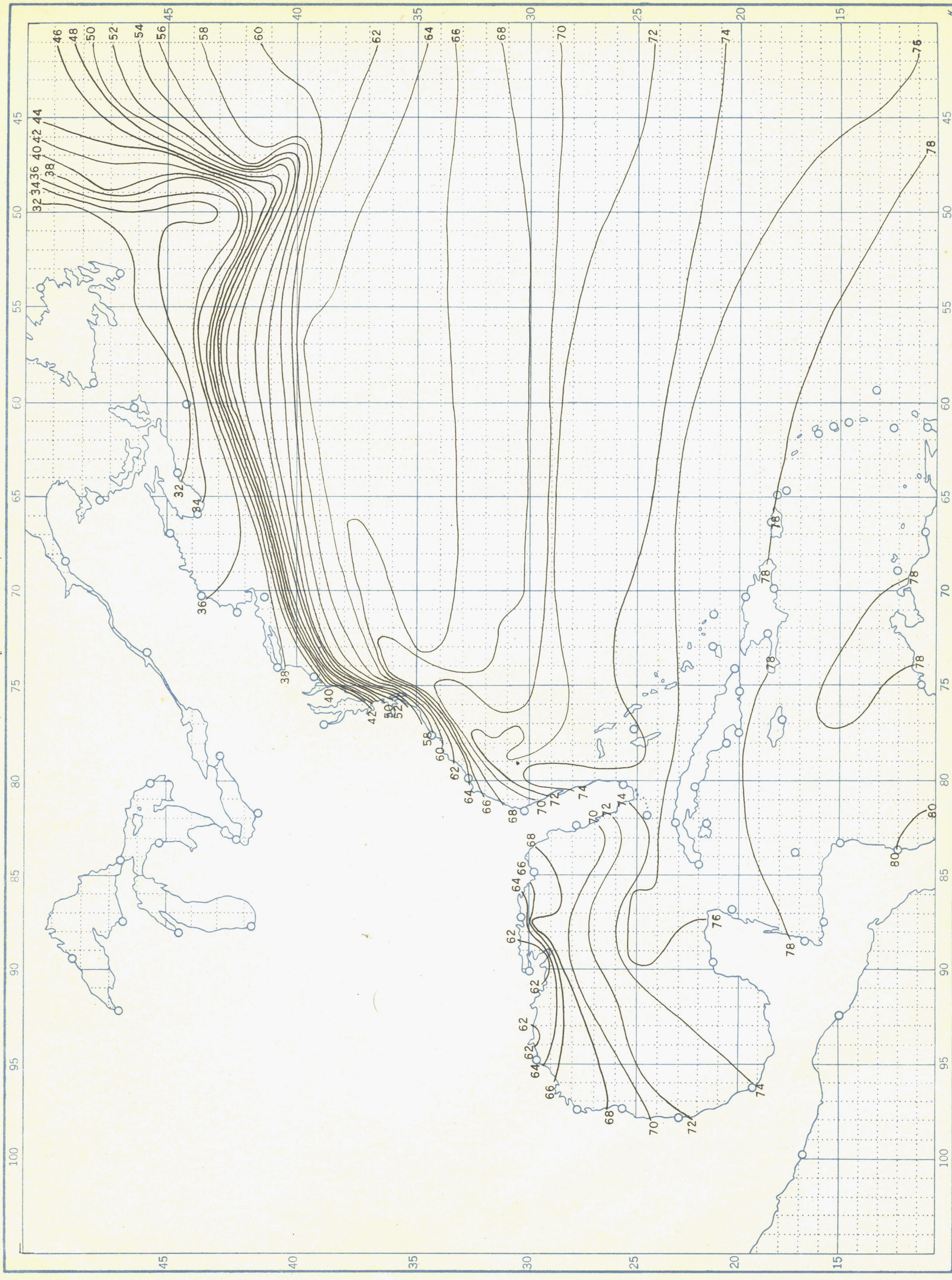


Chart 3. Average Sea-Surface Temperature (°F.) for February 1912-1931
(Plotted by Giles Slocum)

Chart 4. Average Sea-Surface Temperature (°F.) for March 1912-1931

(Plotted by Giles Slocum)

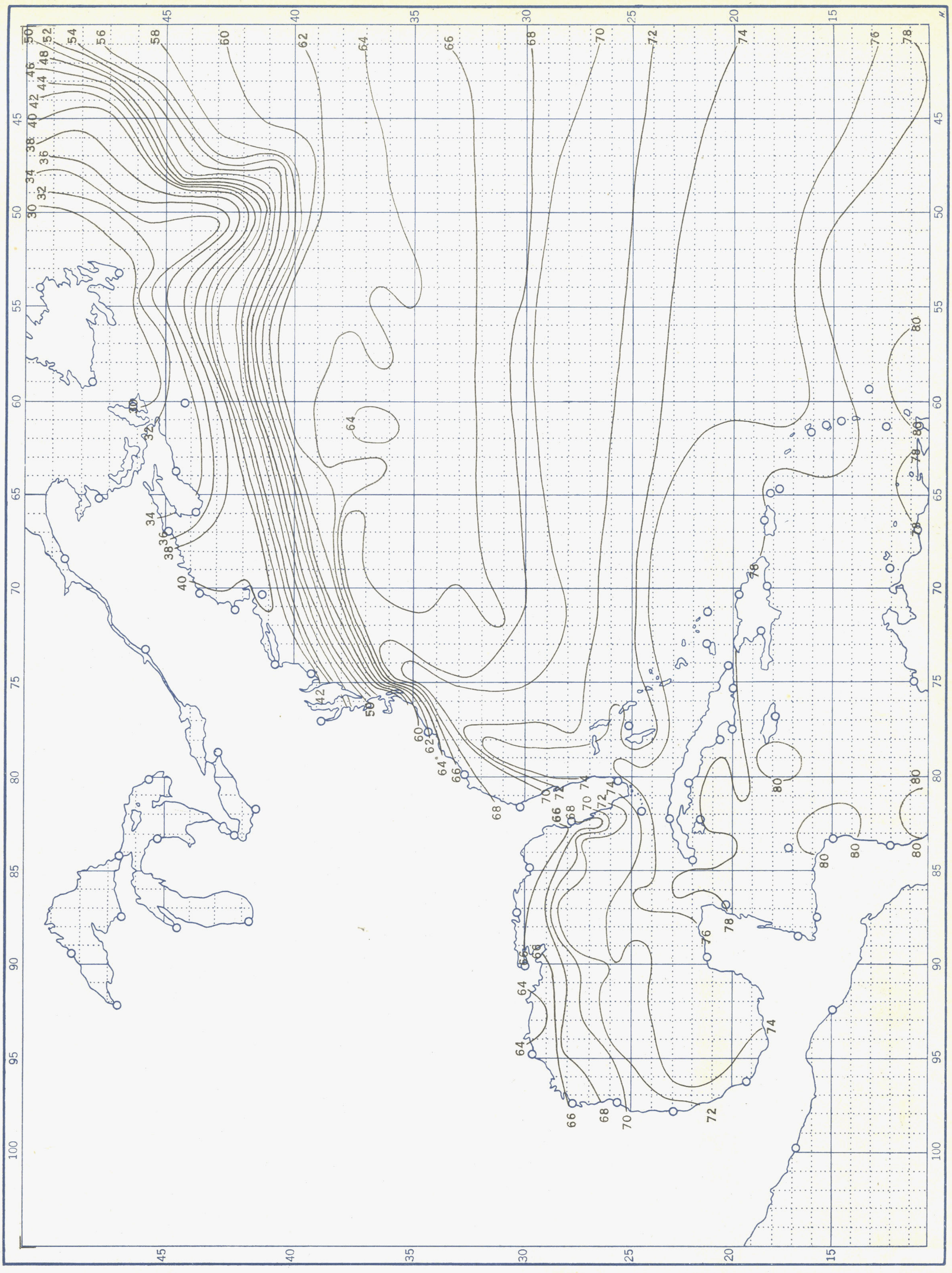


Chart 5. Average Sea-Surface Temperature (°F.) for April 1912-1931

(Plotted by Giles Slocum)

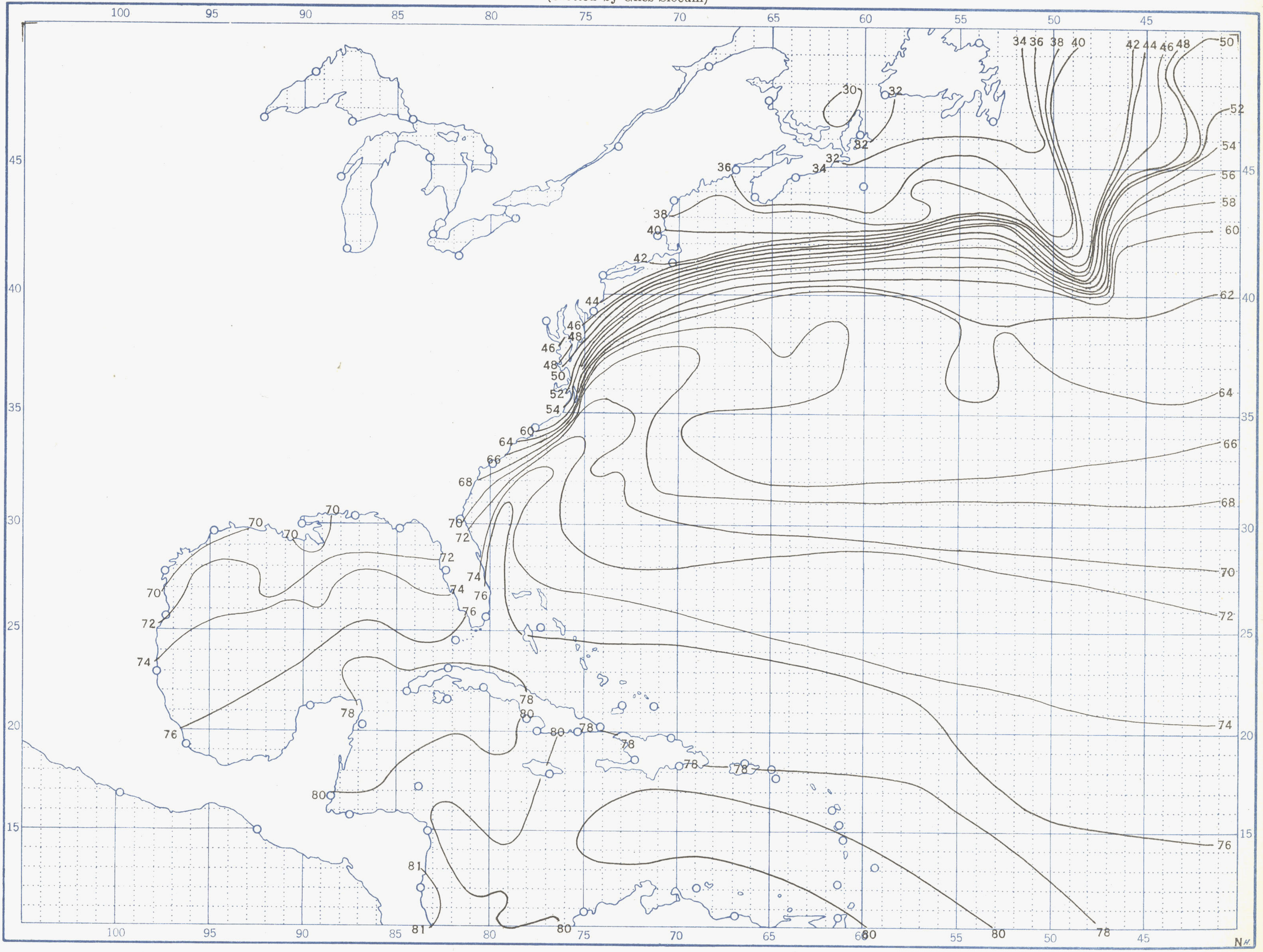
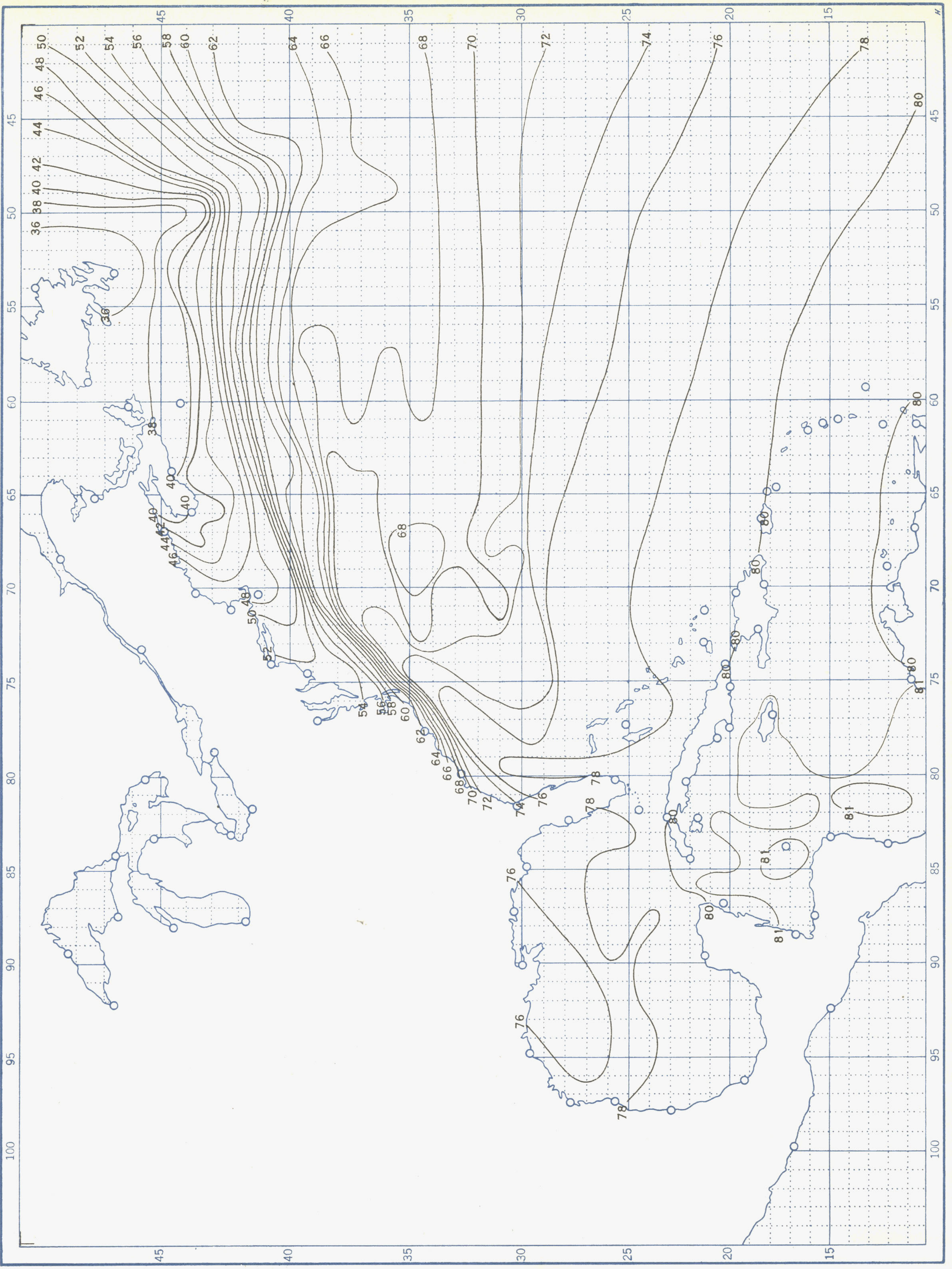


Chart 6. Average Sea-Surface Temperature (°F.) for May 1912-1931

(Plotted by Giles Slocum)



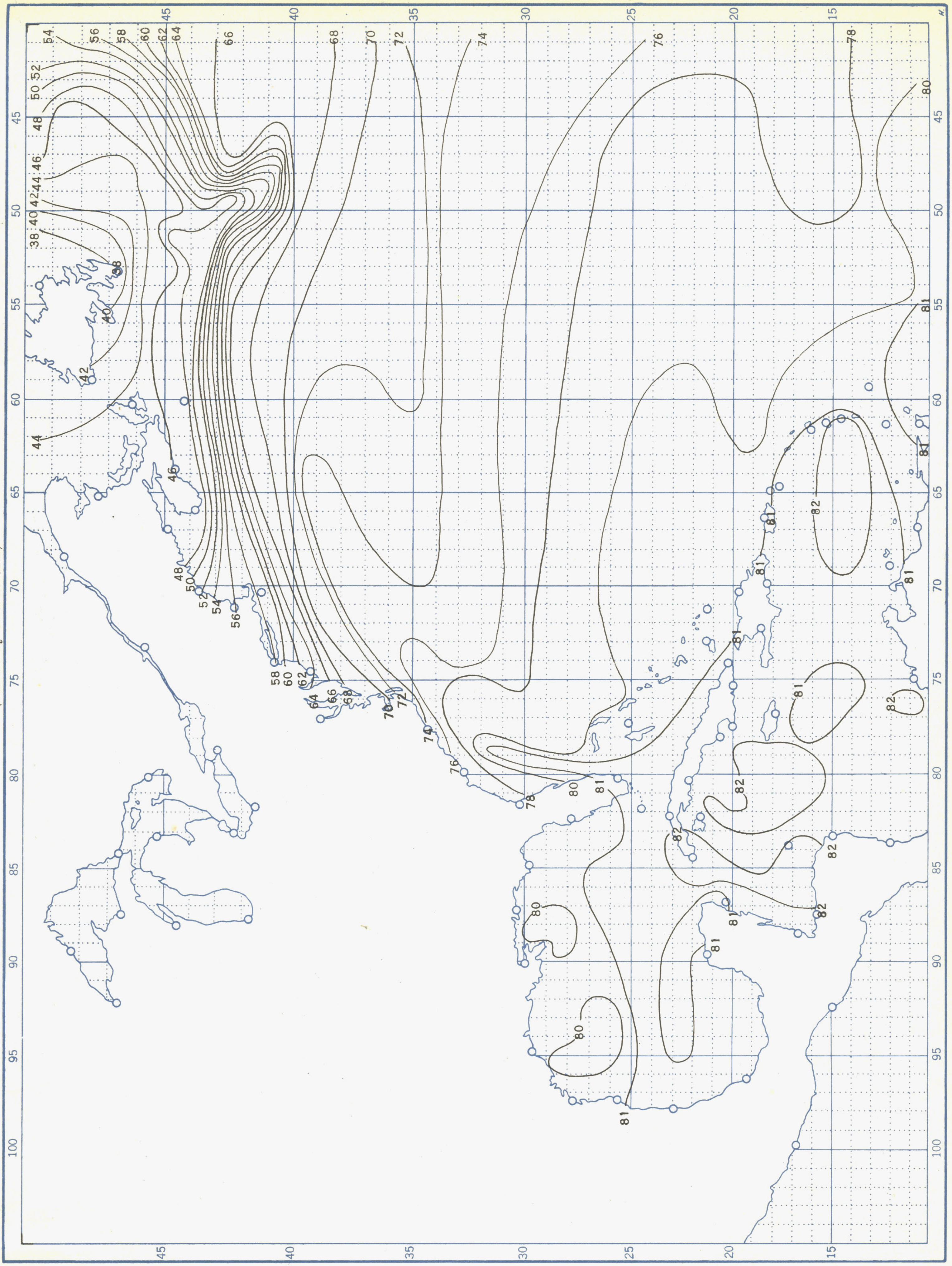


Chart 7. Average Sea-Surface Temperature (°F.) for June 1912-1931
(Plotted by Giles Slocum)

Chart 8. Average Sea-Surface Temperature (°F.) for July 1912-1931

(Plotted by Giles Slocum)

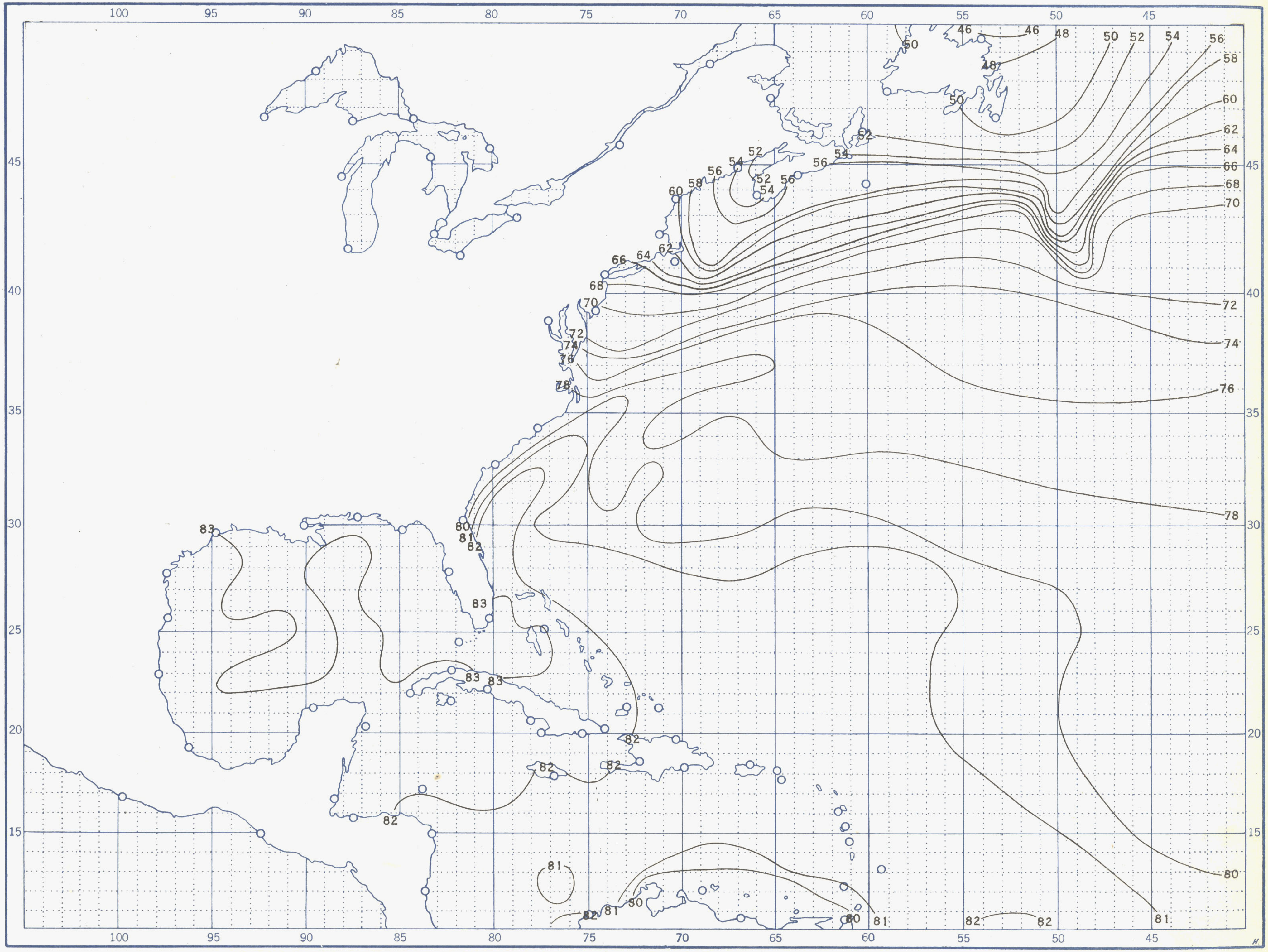


Chart 9. Average Sea-Surface Temperature (°F.) for August 1912-1931

(Plotted by Giles Slocum)

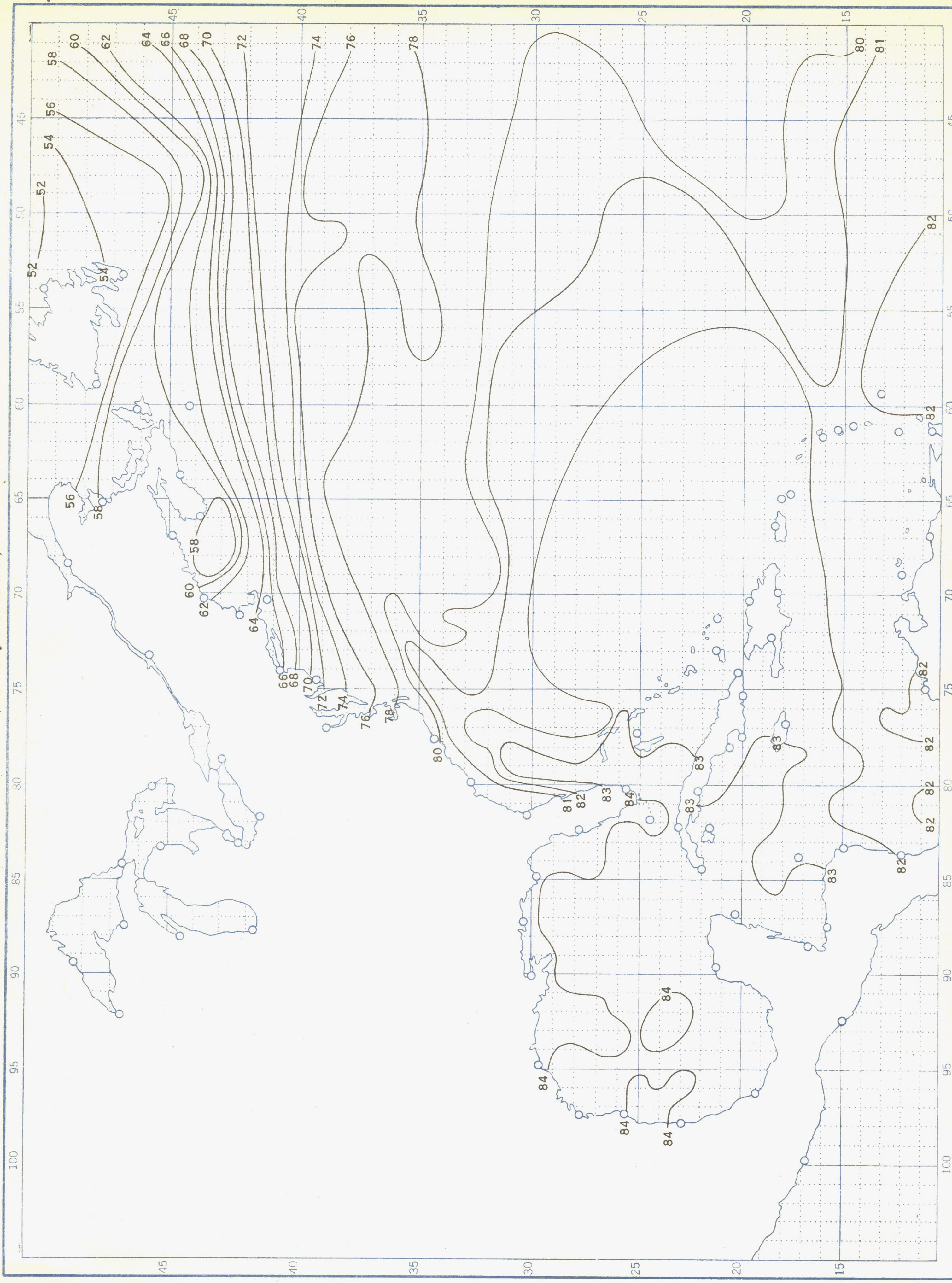


Chart 10. Average Sea-Surface Temperature (°F.) for September 1912-1931

(Plotted by Giles Slocum)

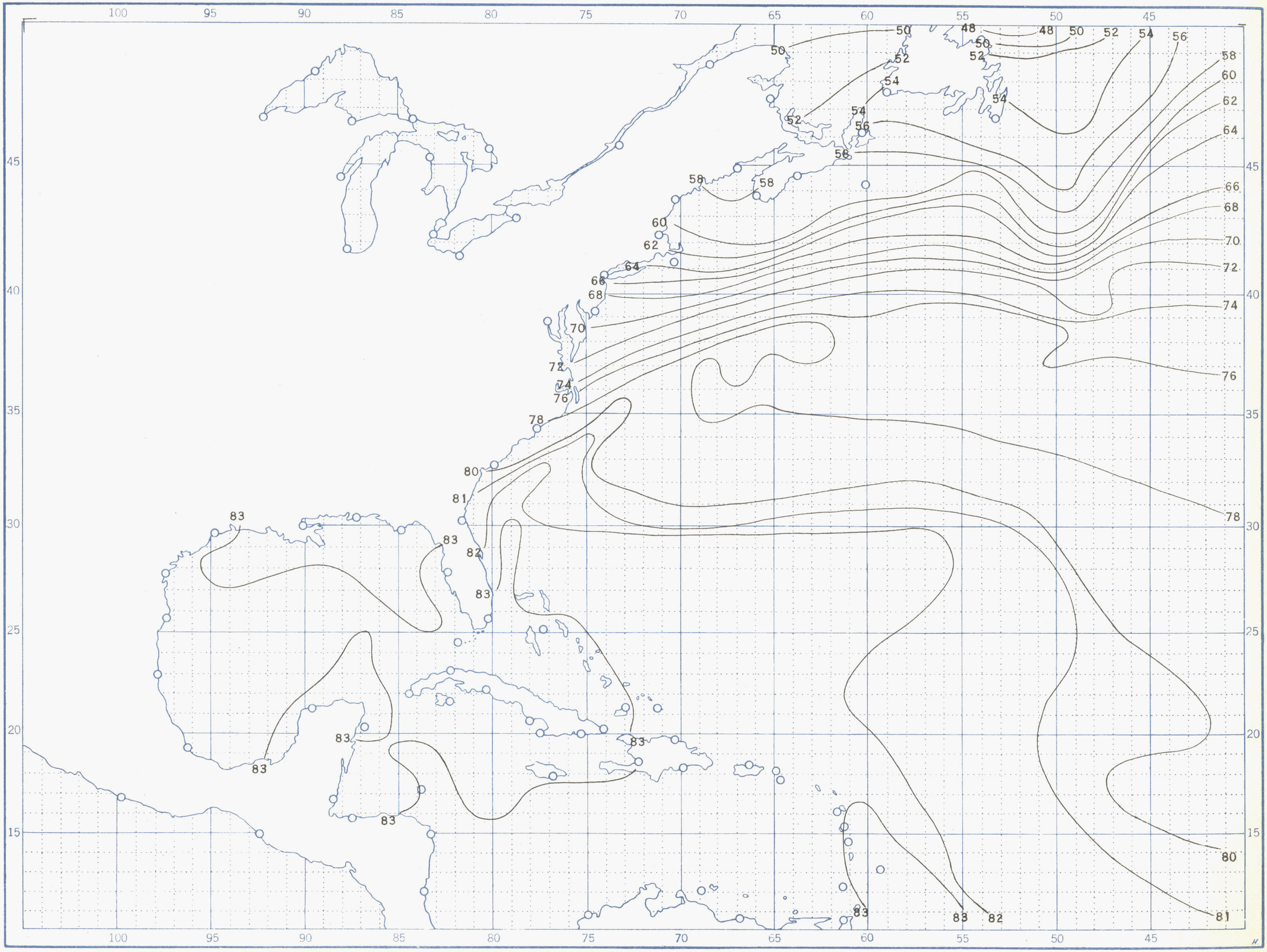


Chart 11. Average Sea-Surface Temperature (°F.) for October 1912-1931

(Plotted by Giles Slocum)

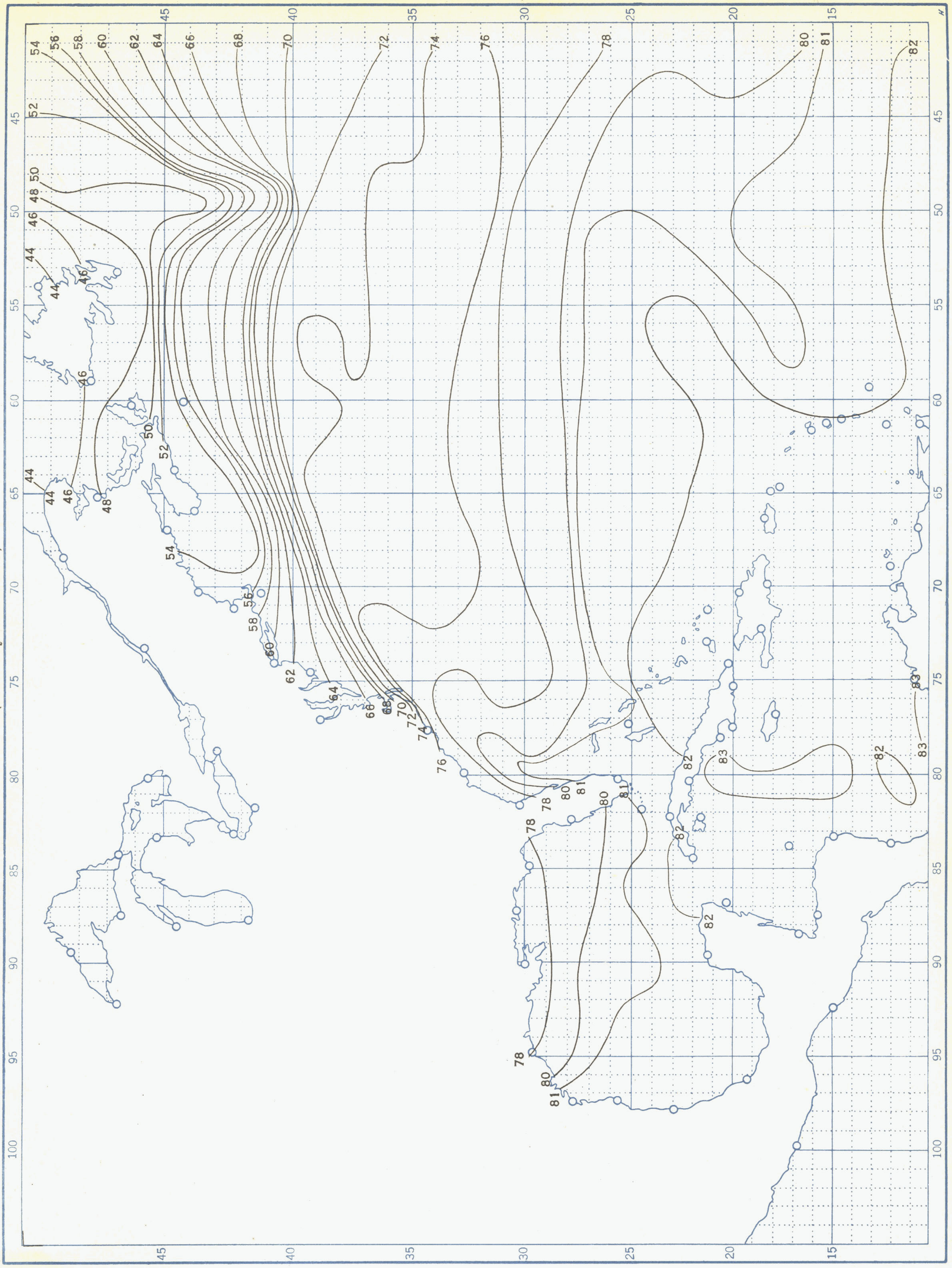
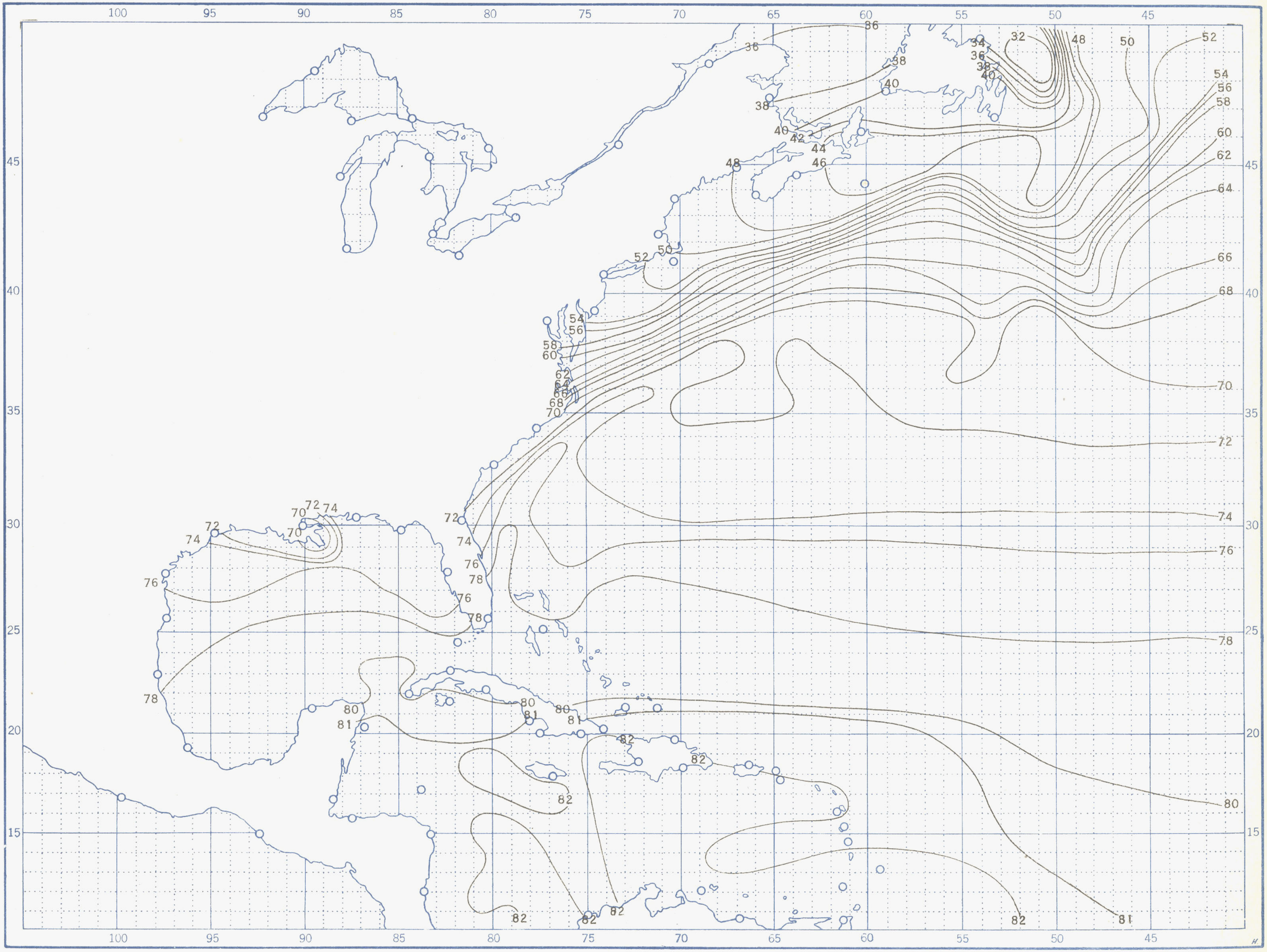


Chart 12. Average Sea-Surface Temperature (°F.) for November 1912-1931

(Plotted by Giles Slocum)



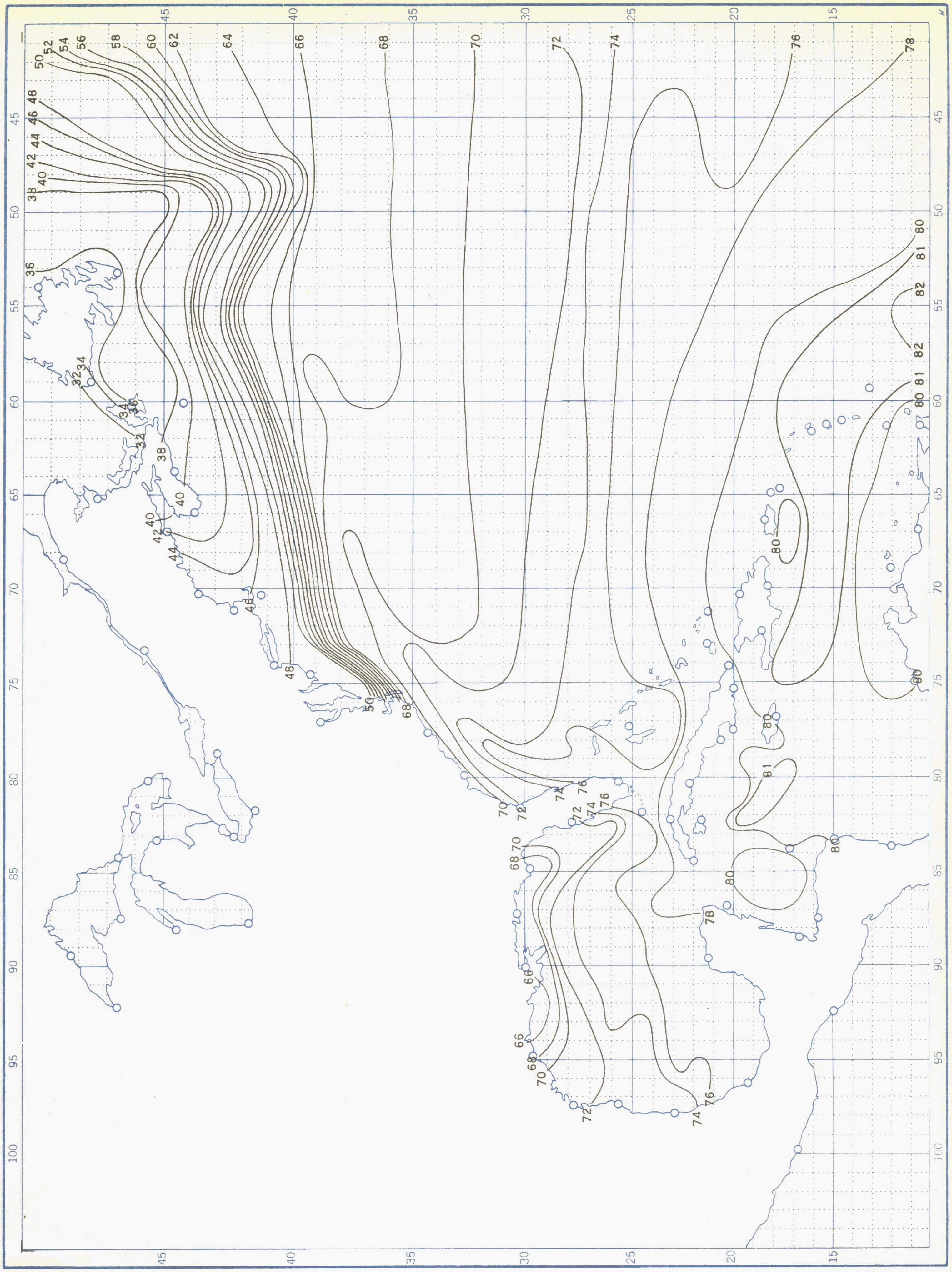


Chart 13. Average Sea-Surface Temperature (°F.) for December 1912-1931

(Plotted by Giles Slocum)

Chart 14. Annual Range of Normal Sea-Surface Temperature

(Plotted by Giles Slocum)

Chart 15. Normally Coolest Month of the Year

(Plotted by Giles Slocum)

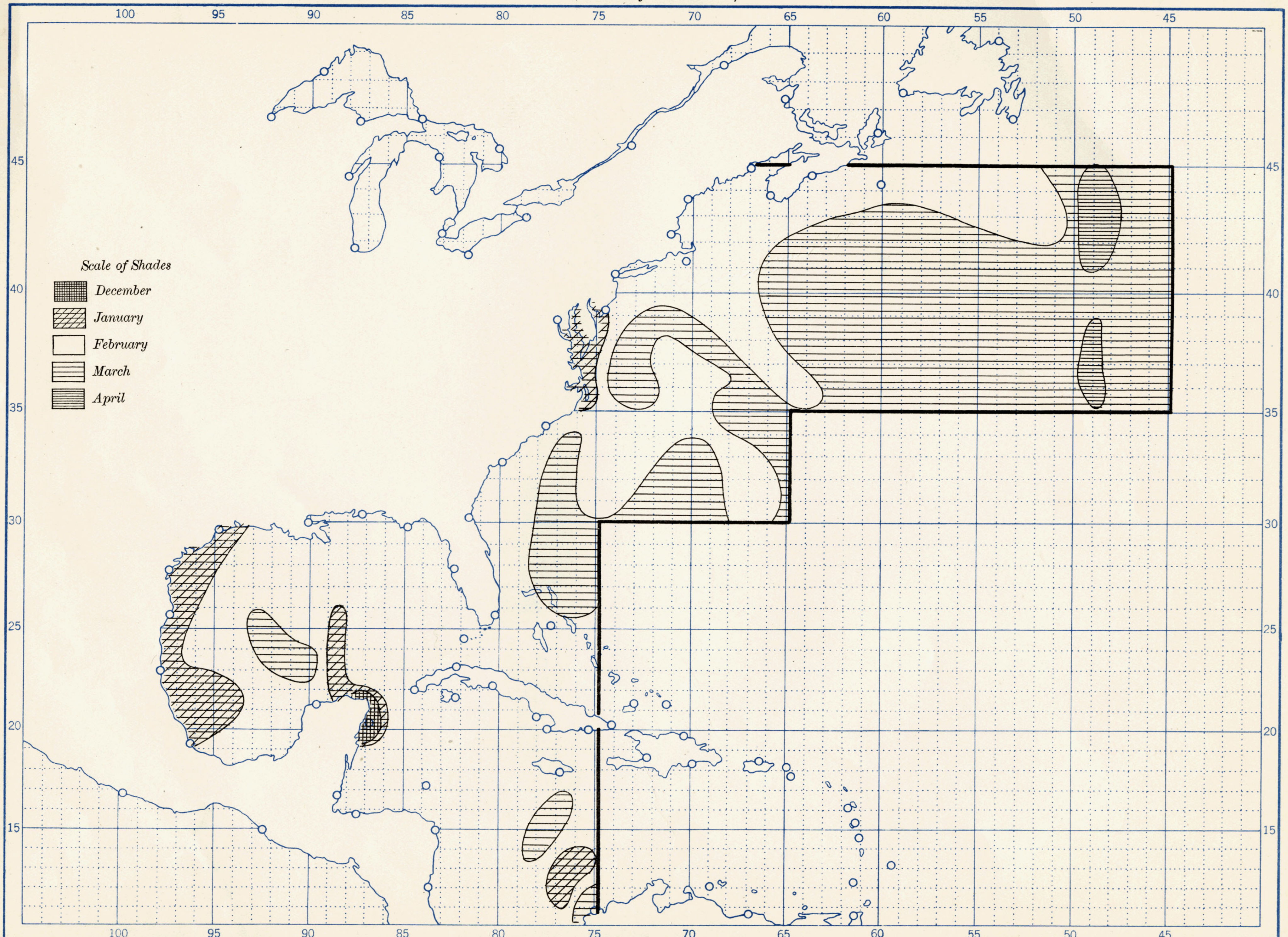
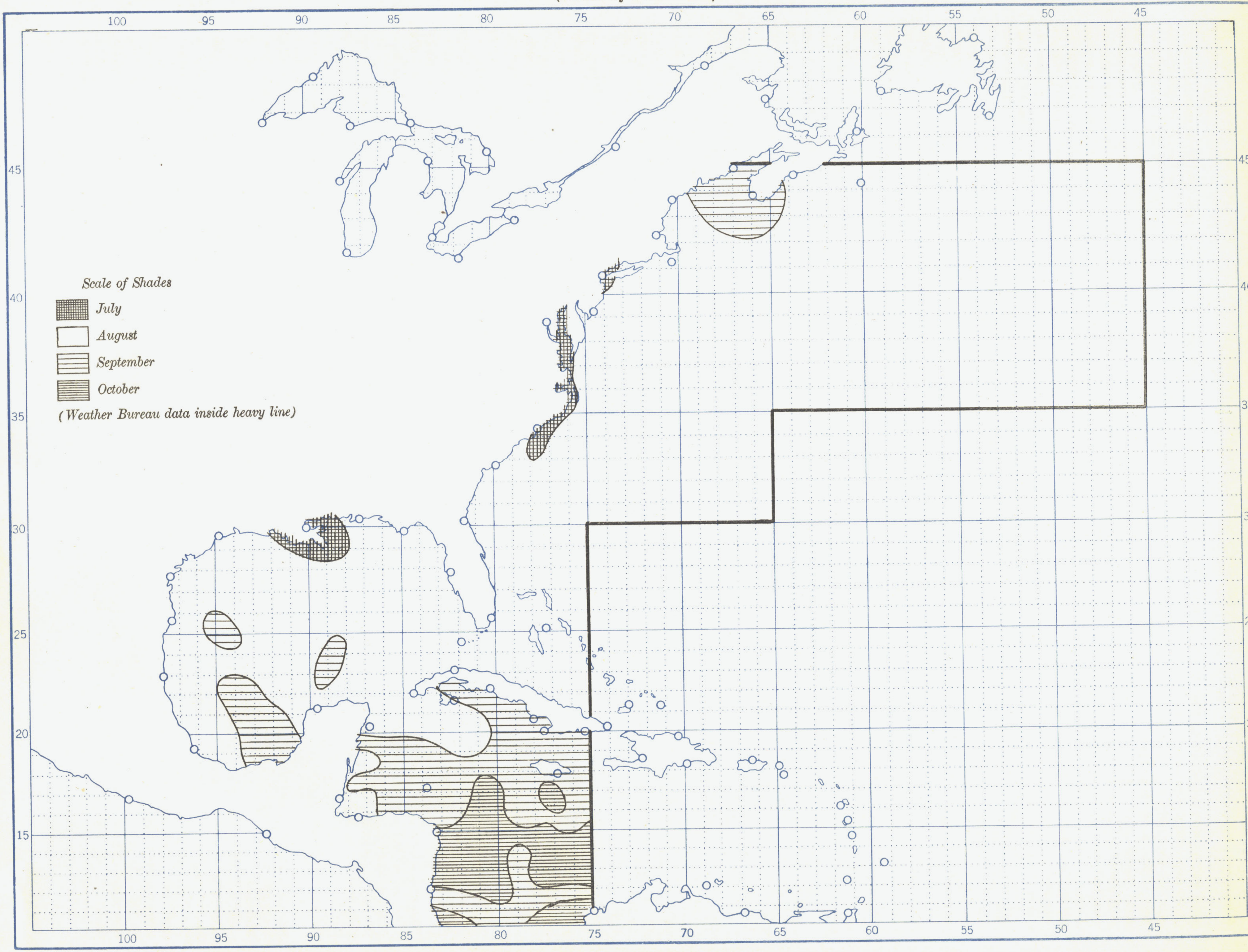


Chart 16. Normally Warmest Month of the Year

(Plotted by Giles Slocum)



ered before the opening of the Panama Canal made the Caribbean Sea the well-traveled ocean thoroughfare it now is, and the normals, of necessity, rested on scanty data. Even in the areas where other compilations have used fairly abundant data, the still richer material now available has allowed the use of a small unit of area, the smallest as yet employed for these waters. The ability to use such a small unit of area is particularly valuable for the western North Atlantic Ocean, where temperature gradients are steep, and geographic origins of the surface water diverse.

The data used in the preparation of the charts were, in the main, gathered after the end of the period covered by the British data, making the material here presented conceivably useful for studies of secular trend in water-surface temperatures.

Charts 2 to 13 are the 12 monthly normal charts prepared from the data here discussed. It will be noted that the isotherms drawn on these 12 charts extend beyond the area shown on chart 1. The isotherms were extended [7] to 40° W. by using the British data published in the 1926 issues of the Marine Observer. For this area, from the boundary of the Marine Division area to the 40th meridian, the British data are about as numerous as those now in possession of the United States Weather Bureau in accessible form, and represent a longer period of years than has as yet been made accessible from the Marine Division files.

Chart 14 shows the range in normal temperature of the water surface from the coolest to the warmest month. This chart, like the 12 monthly normal charts, covers the region as far east as 40° W. The remaining charts extend only to the limits shown on chart 1. As chart 14 shows, the range is about 5° F. south of the Tropic of Cancer. It is less than 15° in much of the northern latitudes, but is more than 15° where the Labrador Current brings cold water southward to be warmed by the intense insolation found in middle latitudes in the summer, and is greatest in the area close to the coast, where water temperature variation is dominantly affected by continental air temperature.

In a given locality, the water-surface temperature remains nearly constant during the months from January to April, inclusive, and again from July to October, inclusive. Chart 15 shows the coolest month, which is February over most of the area but is March over much of that portion of the region north of the thirty-fifth parallel. January is cooler than March or April in the Gulf of Mexico, and is warmer than these months in the greater part of the sections of the Caribbean Sea and the North Atlantic Ocean here included. Chart 16 shows the month which is warmest. July is warmest in very limited areas close to the coast. August is the warmest month over most of the ocean surface represented on chart 16, except in the Caribbean Sea. September is warmest in the Caribbean Sea north of about 13° N., and October is warmest in most of the area south of this parallel.

The Gulf Stream surface waters average slightly warmer than the surface waters immediately to the southward, as far east as the sixty-fifth meridian. To the north of the Gulf Stream the temperature gradient is very steep, and the true temperature gradient at any one time is even steeper than the normal gradients shown on charts 2 to 13. As a corollary, the isothermal lines, representing the true water-surface temperature gradient are more irregular at any one time than the normal isotherms, since the northern margin of the Gulf Stream changes position to a slight extent and because there are invasions of warmer water into the cold-water area and possibly of colder water into the warm-water area. The areas of steep temperature gradient may be considered, therefore, as zones of mixing between warm and cold water masses of widely differing temperatures, and consequently, as zones of variable surface water temperature. Similarly, the widely-spaced isothermal lines on the charts indicate areas where variation of surface-water temperature is mainly seasonal in character, and variations are small from day to day, or, in midwinter and midsummer, are small even from month to month.

In winter, even the greatly flattened-out normal temperature gradient, north from the axis of the Gulf Stream, across the width of the Cold Wall, which appears on the charts as a series of very closely-spaced lines, even after the constant wanderings of the axis of the Gulf Stream and of the margin of the Cold Wall are smoothed out by using the normal temperatures, is the steepest horizontal natural temperature gradient of more than strictly local extent, in the world, except for the midwinter air temperature gradient inland from the Gulf of Alaska to the interior of the Alaskan peninsula. There is another steep water-temperature gradient between the Gulf Stream and the coast of the United States during the cooler months, but this gradient is much less abrupt in the summer, and in places even disappears in the warmest months, whereas the steep gradient between the Gulf Stream and the waters to the north exists both summer and winter, being about half as steep in summer as in winter.

In drawing the charts it can be appreciated that certain deliberate inaccuracies have been necessary because of limitations in resolution of detail attainable in drafting and in the printing process. The isotherms have been placed as close together in some places as was physically practicable, and have even been necessarily omitted on some charts, near to Cape Hatteras, because of their excessively crowded configurations, it is probable that in most of these places, where the lines on the charts are crowded the true normal surface-water temperature gradient is much steeper than is shown. Certain other uncertainties also exist which are due to the inadequacies, already discussed, of the data and no claim can be made for accuracy in the detailed placing of the intersections of the isotherms with the coast line. Usually the observations close to the coast are scarce except near important ports, so that harbor temperatures are almost the only data available. Therefore, while some attempt has been made to trend the lines in the correct directions along the coasts, the principal consideration in the placing of their coastward terminations has been to allow room for the temperature figures.

From the meteorologist's standpoint, it would seem that in most cases little essential information is lost, however, from the necessary coarseness of the method of presenting the data. The important fact is that the temperature gradient at the north margin of the Gulf Stream is so steep that it may be considered essentially a temperature discontinuity of considerable magnitude. The position of this north margin may indeed vary by a few dozen miles in the course of months and be in a different position by this distance from one year to the next at the same season, but again, meteorologically speaking, even this meandering is a phenomenon taking place in a comparatively narrow compass. Consequently, there exists, both summer and winter, century after century, what may be treated as a line of water temperature discontinuity always in essentially the same place.

[7] Cf. Marine Observer, Vol. III, op. cit.

An air mass, moving over the water, and attaining a position athwart the Cold Wall, will be profoundly affected in its properties by this water-surface temperature contrast. For example, the frequent and dense fogs so often observed in the environs of the Grand Banks are formed in warm air masses which pass over the southward-jutting tongue of cold surface water originating in the Labrador Current. As an example in the opposite thermal direction, a southward- or southeastward-flowing air current, moving into the area of the Gulf Stream and the warm North Atlantic Ocean waters beyond it, will be subjected to vigorous convectional overturning, with substantial increase of moisture content. The observed effect of such a polar air mass in reducing the temperatures of these warm surface waters seems to indicate that the thermal transfer is of sufficient magnitude to bring the mean temperature of a layer of cold air 2 miles deep from its original value to one in equilibrium with the surface-water temperature, assuming that convection does not extend above this height, that the exposure time be 2 days, and that the upper 10 meters of the water contribute all the added heat.

The heat capacity of the water is much greater, volume for volume, than the capacity of the air, however; and in the Gulf Stream, movement of the water, both horizontally along the surface and vertically through convection, enters as a controlling factor in maintaining water-surface temperature whenever any important cooling takes place. The result is, that even a succession of cold waves reaching the Gulf Stream will not radically modify its surface temperature, nor greatly impair its ability to heat the next cold air-mass reaching it.

An area was chosen off the Virginia-Carolina capes, as a sample, and a temperature history [8] month-by-month, was compiled for this area, the limits of which are outlined on chart 14. This area was chosen so as to exclude all the cool waters shoreward from the Cold Wall, while including an area of warm water all of which would be close to the continent, and therefore, exposed to the influences of continental air masses modified only by littoral, as distinguished from marine, conditions. The axis of the Gulf Stream usually traverses this area, but the northwestern portions of the region normally occupied by this ocean current are not included, since the variations in temperature are here largely due to the alternate occupation of this area by Gulf Stream water and by cold water of the continental slope. The southern and eastern portions of the sample area lie oceanward from the Gulf Stream, and the surface water is slightly cooler in these portions than in the Gulf Stream, the average difference being slightly over 1 Fahrenheit degree. The solid line on figure 1 shows the annual march of the normal temperature for this area, the coldest month being February, with a normal of 65.8°, and the warmest, August, 79.8°. The dotted lines show the temperatures of the extreme warmest and coolest months in 20 years' record for each month of the year. In determining the positions of the dotted lines, however, months with less than 15 observations were not considered. The indicated averages for such months based on such observations as were available when these averages were higher or lower than those selected by this arbitrary criterion of 15 observations as a minimum, are shown by dots, with the year in which they were found shown in the footnote to the figure.

It can be seen that, while the range of possible mean temperature of the surface water in this area is an appreciable fraction of the annual range, it is yet, on an absolute scale, not very important. Since this area was chosen as a sample in which the continental temperature influence would be at a maximum for warm-water areas within the region covered by the charts, we may conclude that the seasonal normal temperature of the surface water in a given portion of the western North Atlantic Ocean is a good measure of the actual temperature in that portion at any given time.

It could be wished that more accurate data be made available, but greater precision than that afforded by the

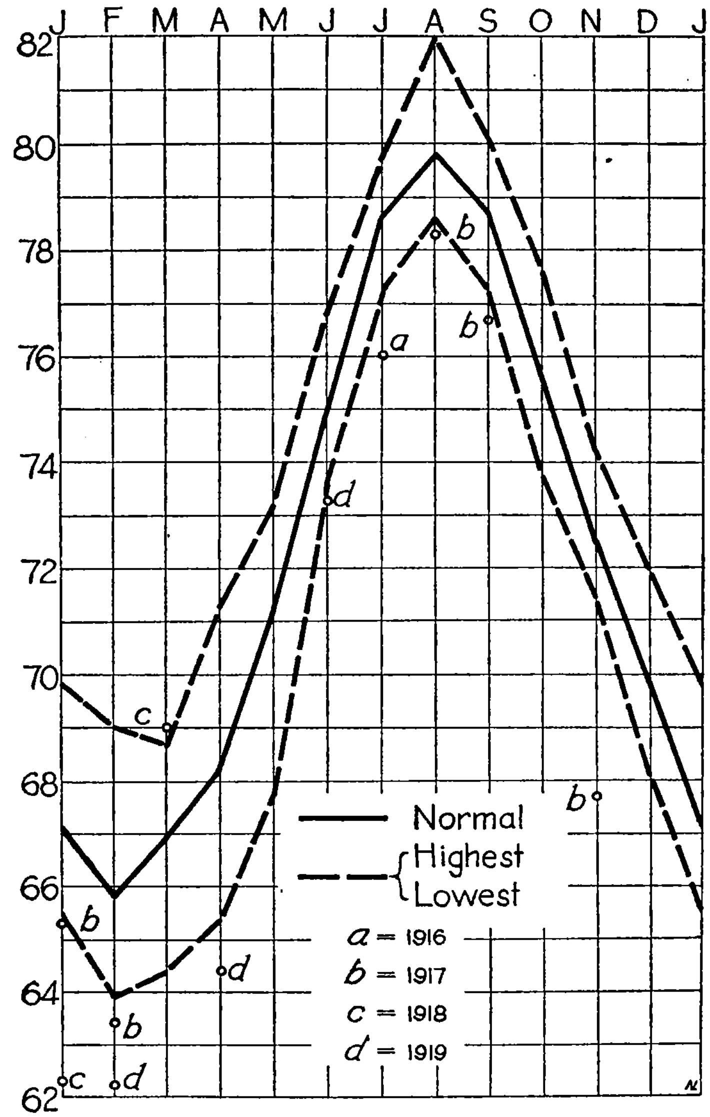


FIGURE 1.—20-year normal, and extreme highest and lowest monthly sea-surface temperatures for an area off the Virginia-Carolina capes (°F.)

monthly normal can only be obtained by overcoming formidable difficulties, which would be further multiplied if the day-by-day surface water temperature situation should be required on the same day in which the observations be made. It is believed, therefore, that the monthly normal conditions, as shown on the accompanying set of 12 charts, constitute as close an approach to the synoptic condition as it is at present practicable to reach, and that these charts can be used with nearly as much confidence, as a partial basis for daily forecasting purposes, as could the most ideally adequate synoptic charts of water-surface temperatures for this region.

It would perhaps be worth while, however, to obtain a

[8] This temperature history may be found in MONTHLY WEATHER REVIEW, vol. 65, p. 461, December 1937.

much larger number of observations from the waters within a degree or two of the coast of the United States and outside the areas covered by the convergence of important steamer lanes. Such an increased number of offshore water-temperature observations would be useful, since the majority of inquiries concerning water-surface temperatures which come to the Weather Bureau from outside the professional meteorological and oceanographic circles, are for temperatures largely within these coastal waters, for which, as shown on chart 1, the Marine Division has fewest observations available per 1° square. In one case, for example, an inquirer asked the Weather Bureau to furnish the average temperature departures from normal for each of several days in an area of less than a degree in extent. The Marine Division receives about one observation a year from this particular small area, while at least 10 observations a day would be needed to compute even the probable sign of a departure from normal for each of a succession of days. This would be about 4,000 times as many observations per year for the area as are now available.

The making of requests far beyond the existing limitations of the number of available observations and the capacity of the Marine Division personnel is not confined, however, entirely to the nonprofessional inquirer. An eminent scientist outside the Weather Bureau, at one time requested that the water-surface temperatures for each five-mile zone of distance from land be separately classified in the Marine Division tabulations of nearshore water temperatures, for two areas, one of which is indicated on chart 1 as an area from which the Weather Bureau cannot depend on as many as one observation a month for even a strip 70 miles wide and 70 miles long.

The Marine Division answers such inquiries to the best of its ability, and an attempt is made to supply all feasibly available information. Many of the requests for information, even some with which it is impossible to comply because of limited facilities and personnel, are entirely reasonable. A large class of these inquiries can be answered, in part at least, and for the first time by the present set of charts. It is hoped that these charts will therefore prove helpful not only to the forecasters for whom they were primarily intended, but also to the casual, but serious-minded student of meteorology or oceanography as well.

NOTES AND REVIEWS

The Effect of the Magnetic Storm, January 22–26, 1938, on Telegraphic Transmission.[1] By CHARLES M. LENNAHAN. On January 22, 1938, the reception of telegraphic signals of the regular 7:30 a. m., eastern standard time, weather observations was seriously delayed at the San Francisco district forecast center. It was not until 12:23 p. m., eastern standard time, that the final sheet of signals was received. This unusual situation was the result of interference in telegraphic transmission caused by one of the severe magnetic storms accompanying the present period of maximum sunspot activity; brilliant auroral displays were also observed, especially on January 26.

The interference in telegraphic transmission was most pronounced on the transcontinental lines; it began on January 22 and increased in intensity until the afternoon of January 25, at which time the potential induced in the transmission lines was occasionally in excess of 400 volts in many parts of the country. When these foreign potentials exceeded the potentials regularly used on the telegraph circuits, operation had to be suspended. A similar situation existed on the ocean cable circuits. The surges of electricity induced by the storm seldom lasted more than 10 minutes, but the frequency with which the surges occurred and the rate at which the potential increased from zero to a maximum were the greatest ever experienced. However, the telegraph lines were not affected as much as during previous years because of improved methods recently developed and inaugurated to combat such interference.

After the maximum interference was reached on January 25, conditions improved rapidly and the circuits were back to normal on the afternoon of January 26.

Auroras of January 21–22 and 25–26, 1938. By WILLIS E. HURD. At 2:27 a. m. of January 22, 1938, Second Officer Flint, of the American steamer *Coast Merchant*, bound from Tacoma to Bellingham, Wash., observed what he termed "a very unusual display of Aurora Borealis." The ship was then off Alki Point. Fifteen minutes after the first reddish auroral glow was seen, the entire northern half of the sky was alight with beams of various colors that extended toward the zenith, while in the southern sky the streamers were mostly white. The display, with irregular but generally diminishing intensity, lasted until daylight.

During the night of the 21st–22d, the phenomenon of the Northern Lights was visible over much of the western part of the United States, accompanied by magnetic disturbances. At Roswell, N. Mex., on the 21st, it was reported by the Weather Bureau as being the first known occurrence of the character in that vicinity, and at San Diego, Calif., on the morning of the 22d, as the third of record there. It was seen at least as far to the eastward in the United States as Lacrosse, Wis., on the 22d; and was in addition reported near 30½° N., 75° W., by the American steamer *Chilore*, in the North Atlantic.

The auroral display of January 25–26 was even more magnificent and widespread, but was especially pronounced over Europe, the North Atlantic Ocean, and the eastern part of the United States and Canada. Isolated reports from the Weather Bureau Offices at Huron, S. Dak., and Madison, Wis., show that it was also seen faintly in localities to the westward.

The phenomenon, where seen in richest form and coloring, was observed from about 6:30 p. m. (local) of the 25th until approximately 1 a. m. of the 26th. This aurora, according to E. W. Barlow, in The Meteorological Magazine (London) for February 1938 "was accompanied by a great magnetic storm." In parts of the northeastern United States there was some interruption to telegraphic communications.

According to Nature (London) in its issue of February 8, 1938 (vol. 141, pp. 232–235): "Three periods of brilliant display were noted, around 7:45, 8:30, and 9:45. The main features noted were red glows in the northwest and northeast, with a low green arc between during the early stages, green and white rays traversing a bright red glow in the north-northeast about 7:45, and rapidly fluctuating green streamers between northwest and northeast about 9:45."

In the eastern United States, as well as on the North Atlantic Ocean, the predominant color was a pinkish to dull red, but often with light beams cast against the ruddy background. At Providence, R. I., the aurora was extremely vivid from sunset until 7:45 p. m., with great

[1] This note is based on information supplied by Maj. E. H. Bowie, Official in Charge, Weather Bureau Office, San Francisco, Calif., and by J. C. Willever, first vice president of the Western Union Telegraph Company.

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